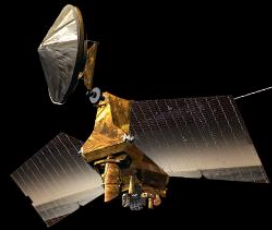




Jet Propulsion Laboratory  
California Institute of Technology

# In the Blink of the Eye: What 10 Years at Mars with *Mars Reconnaissance Orbiter* Can Tell Us About the Planet



**Leslie K. Tamppari**  
Deputy Project  
Scientist, Mars  
Reconnaissance Orbiter

Jet Propulsion Laboratory, California Institute of Technology

# Outline

- Why explore Mars?
- Mars Reconnaissance Orbiter overview
- Science results
- Support of other missions



# Why Explore Mars?

Did Life ever arise on Mars?  
If so, is it still there?

Was the early climate more Earth-like? Why has it changed?

Mars: A destination for  
human exploration?





# FOUR MARS SCIENCE GOALS

1

WATER

## LIFE

Determine if life ever arose on Mars

2

HABITABLE ZONES

## CLIMATE

Understand Martian climate processes and history

3

SIGNS OF LIFE

## GEOLOGY

Determine how the surface and interior of Mars evolved

4

## HUMANS

Prepare for human exploration



EVOLVING THEMES

# Outline

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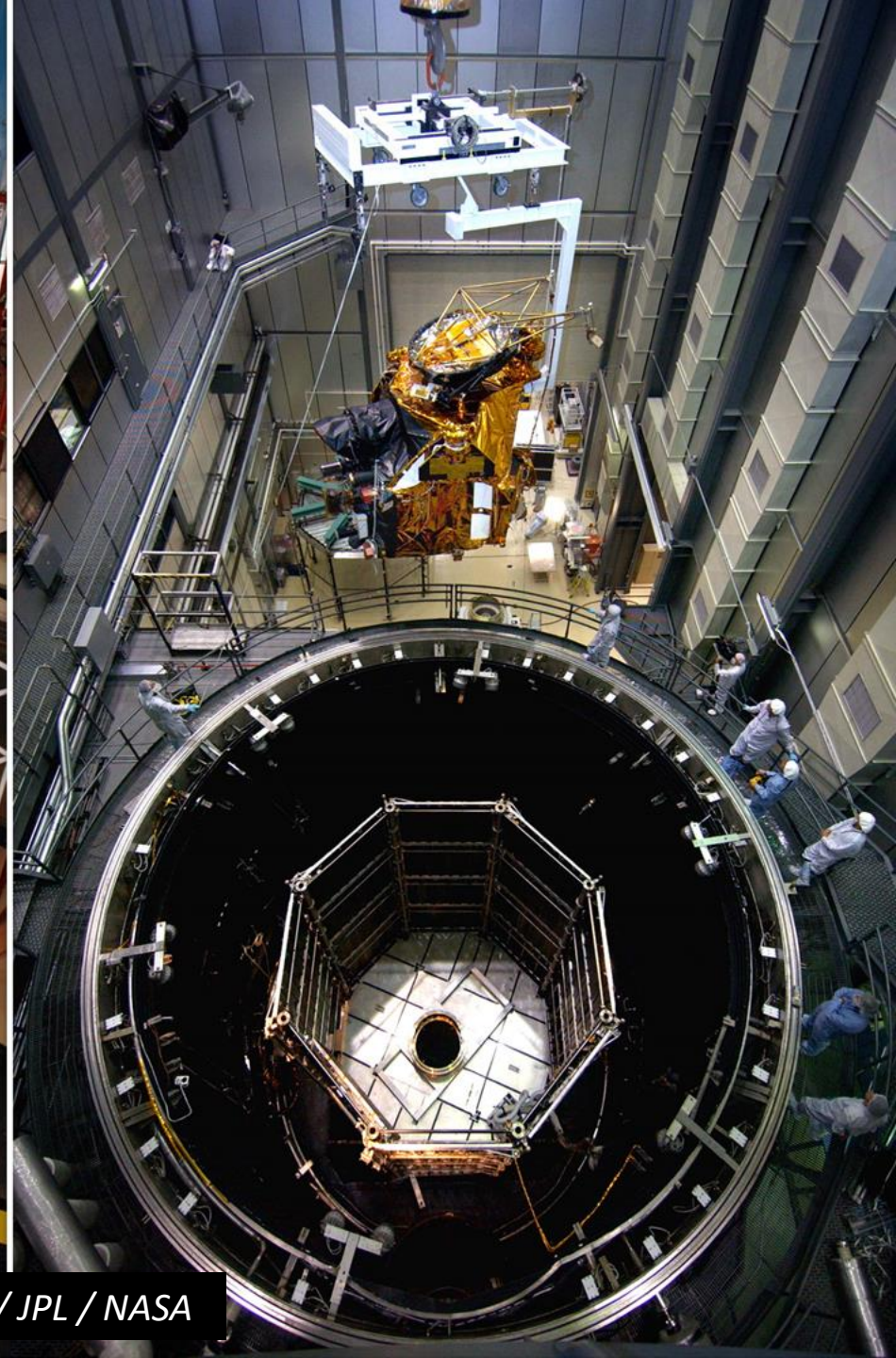
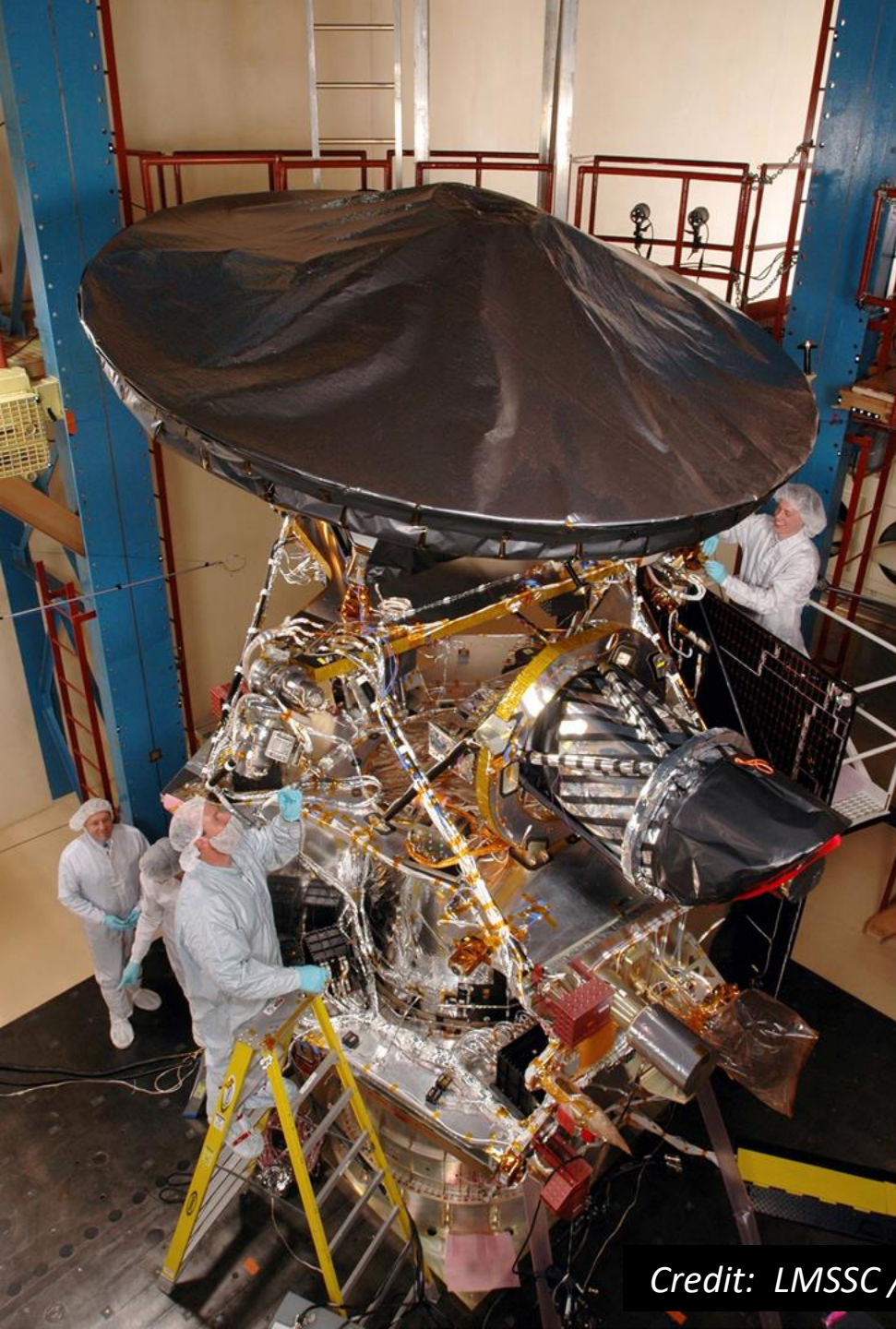


JPL

# Mars Reconnaissance Orbiter







Credit: LMSSC / JPL / NASA



**Launch: August 12, 2005**





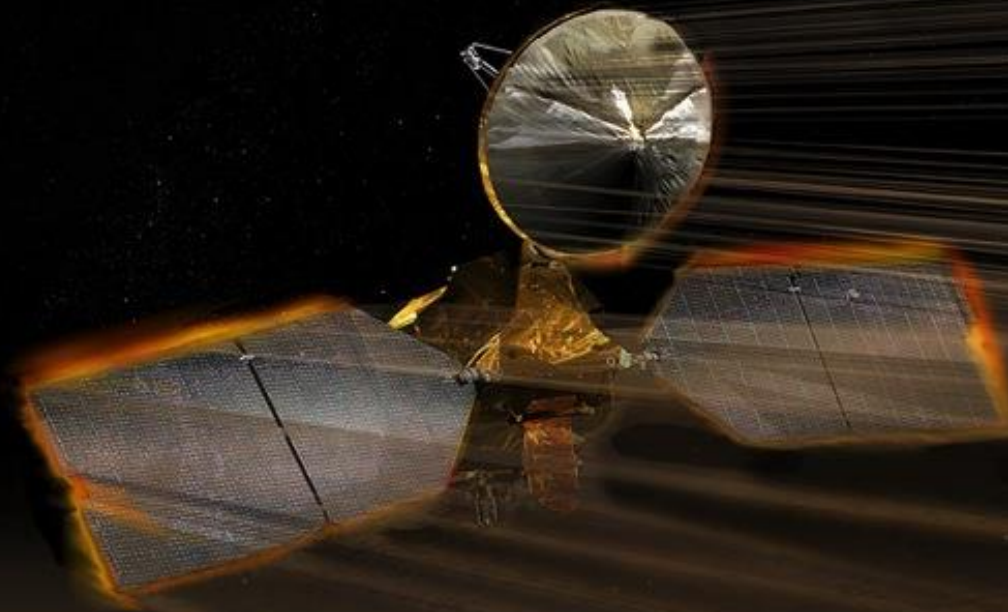
# Into Mars Orbit March 10, 2006



Artist's Concept

*Credit: LMSSC / JPL / NASA*

# Aerobraking: March - August 2006



*Artist's Concept*

*Credit: LMSSC / JPL / NASA*



# Mars Reconnaissance Orbiter Science Investigations

**CRISM**



Hyperspectral Imager  
Visible: near-IR  
18 m/pixel

**HiRISE**



High-res Imager  
Visible: 30 cm/pixel

**CTX**



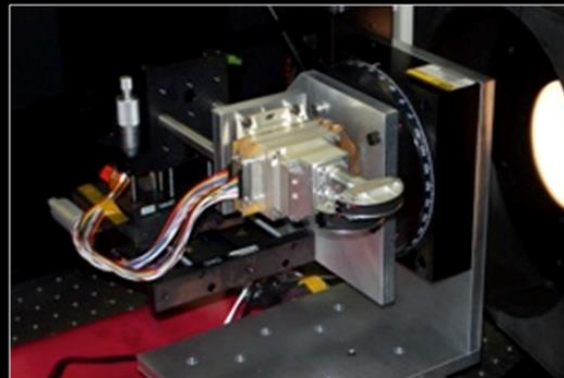
Context Imager  
Visible: 6 m/pixel

**SHARAD**



Radar - subsurface  
10 m to 2 km depth

**MARCI**



Global weather camera  
Visible - UV: 1 km/pixel

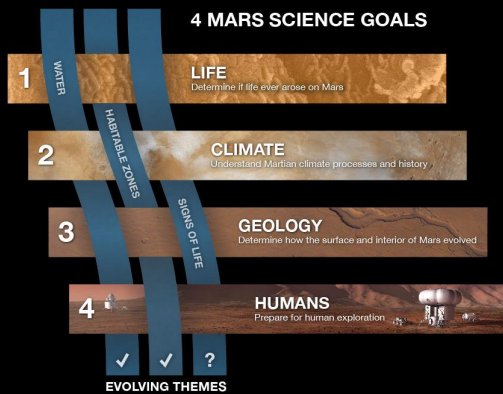
**MCS**



Atmospheric profiler  
Temperature, pressure, dust, ice  
5-80 km altitude

# MRO addresses Mars program themes

*“Follow the Water” and “Search for Habitable Zones”*



- ***“Follow the water”***
  - Ancient aqueous minerals – CRISM
  - Water-related landforms – HiRISE, CTX
  - Subsurface water-ice – SHARAD
  - Atmospheric water-ice – MCS, MARCI
- ***“Search for Habitable Zones”***
  - Minerals indicative of various pH values, salinity – CRISM
  - Aqueous minerals – CRISM
  - Landform morphology – HiRISE, CTX
  - Evaluate present-day climate – MCS, MARCI



# Outline

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# MRO Science Results in Three Mars Eras

**Ancient Mars**

**Recent Mars**

**Present Mars**



# MRO Science Results in Three Mars Eras

**Ancient Mars: Wet environments, some habitable**

**Recent Mars**

**Present Mars**

# What did we know about *ancient* Mars in 2005?

- Ancient Mars (> 3.7 Bya)
  - We knew it was wet, but didn't know the extent of different types of wet environments
  - Thought that Mars changed from wet/neutral pH to dry/acidic
  - Didn't understand the extent of possible habitable environments
- Recent Mars
- Present Mars



# Search for Different Minerals and Landforms that Indicate Different Processes & Environments



**Deltaic sediments: clays**



**Lakebeds: sulfate, chloride, carbonate**



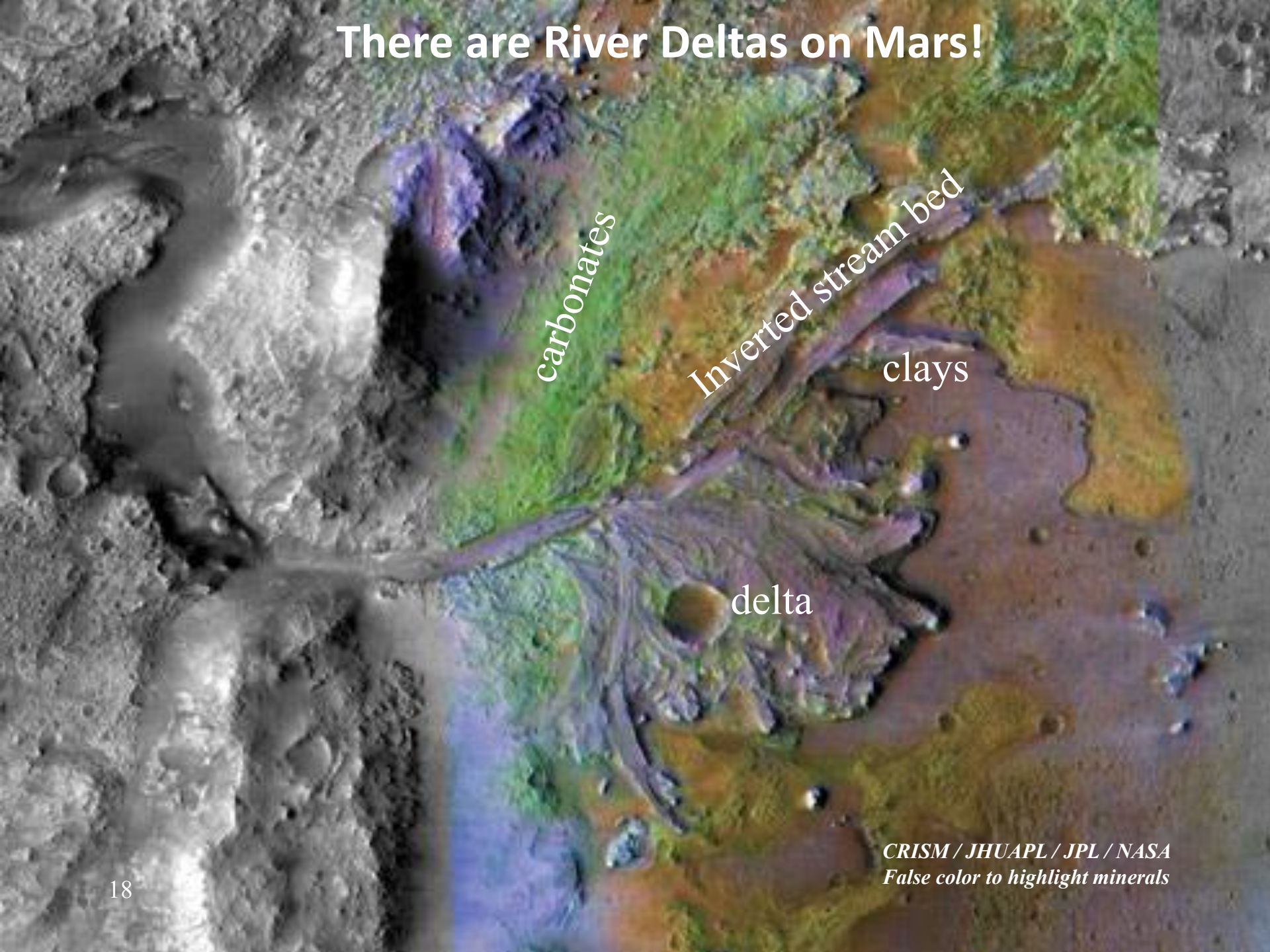
**Hot springs: silica, clays, iron oxides**



**Metamorphism: Phyllosilicates, chlorite, prehnite, serpentine**



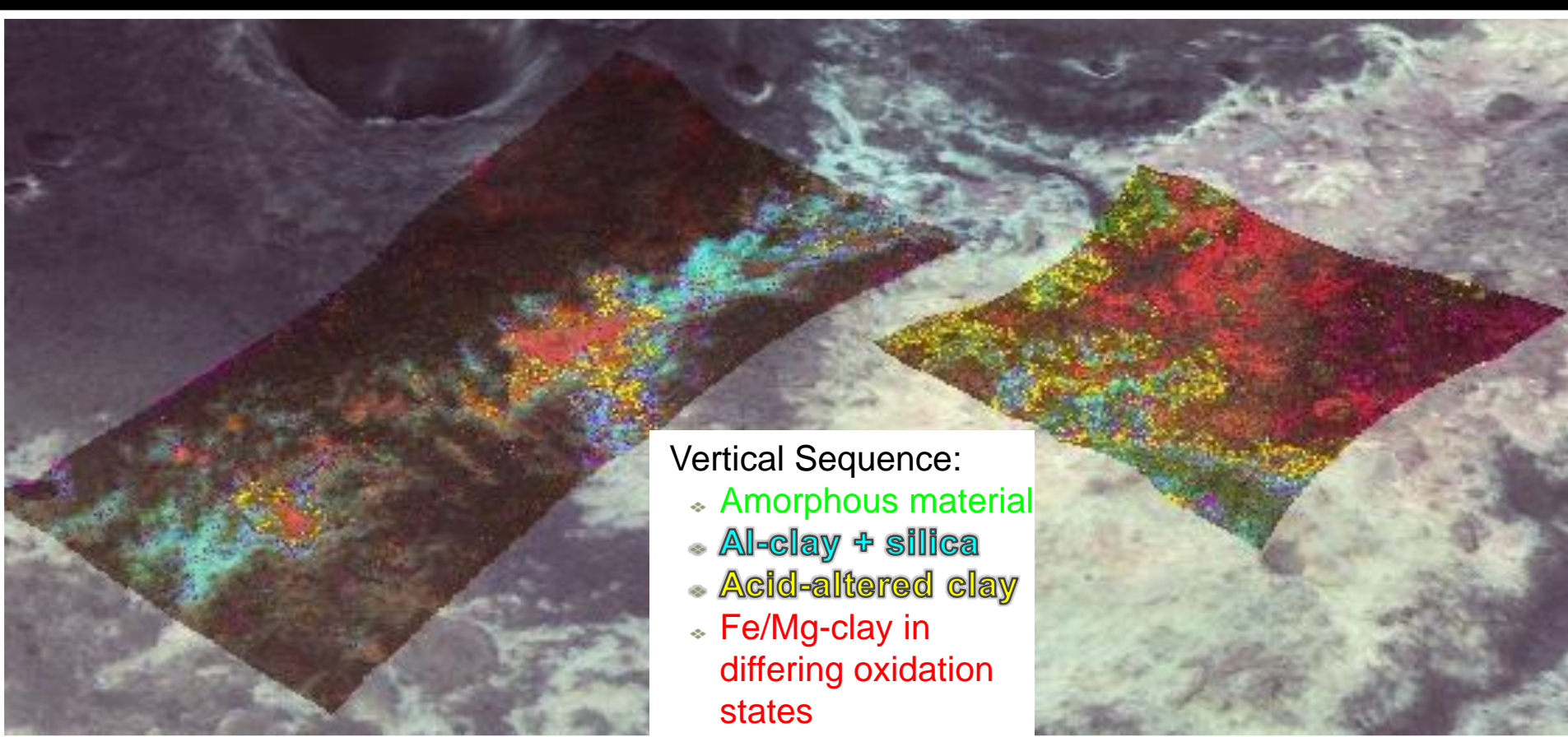
# There are River Deltas on Mars!



*CRISM / JHUAPL / JPL / NASA  
False color to highlight minerals*

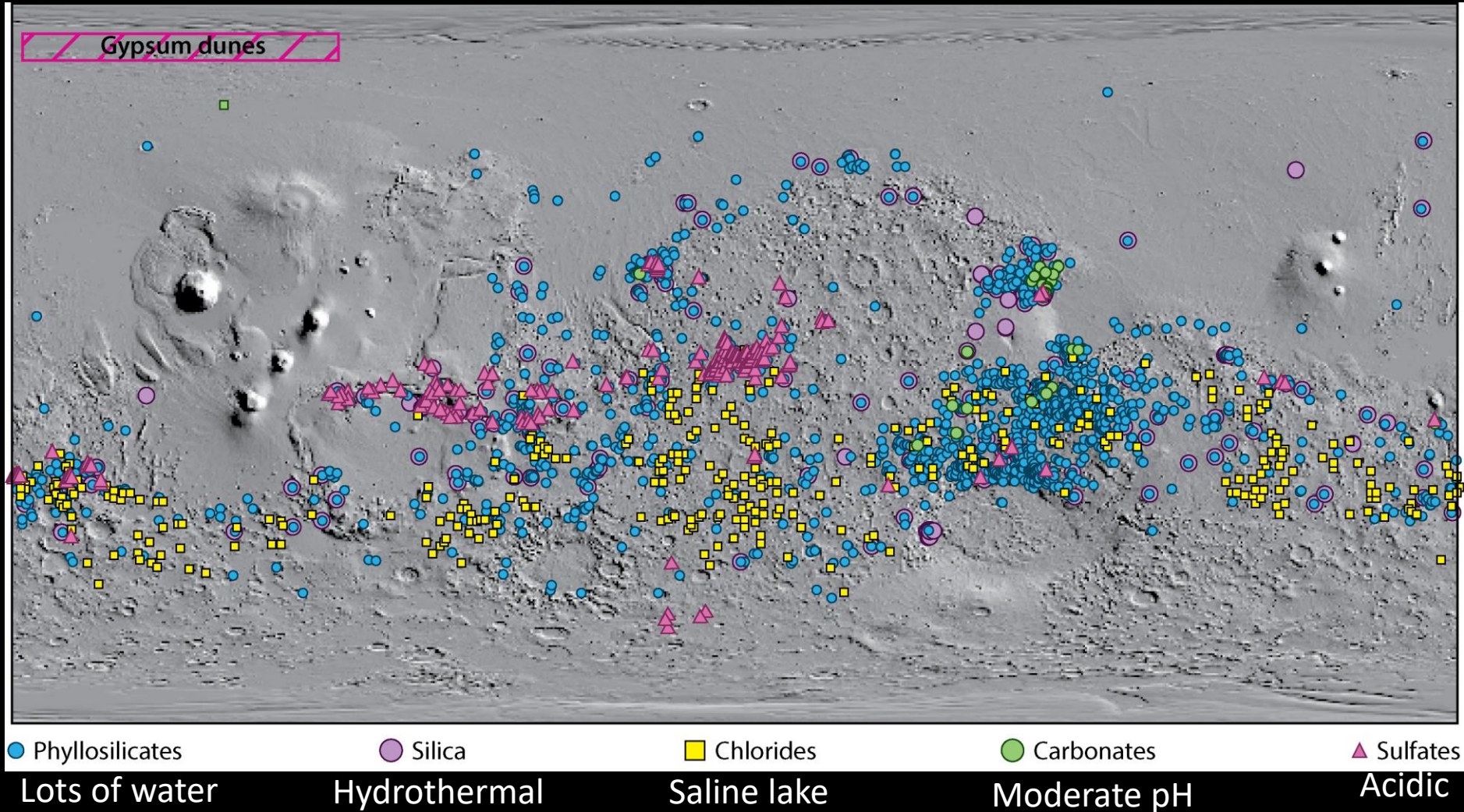


# Mawrth Vallis – A Transitional Environment



- A lot of water required
- Environment transitions from neutral to more acidic upsection
- Possibly a habitable location

# CRISM mapped thousands of minerals outcrops that must have formed in liquid water across the planet



**Their sequence in time tells the story of Mars' habitability**

*Ehlmann and Edwards (2014) Ann. Rev. Earth Plan. Sci.*



# MRO Science Results in Three Mars Eras

**Ancient Mars**

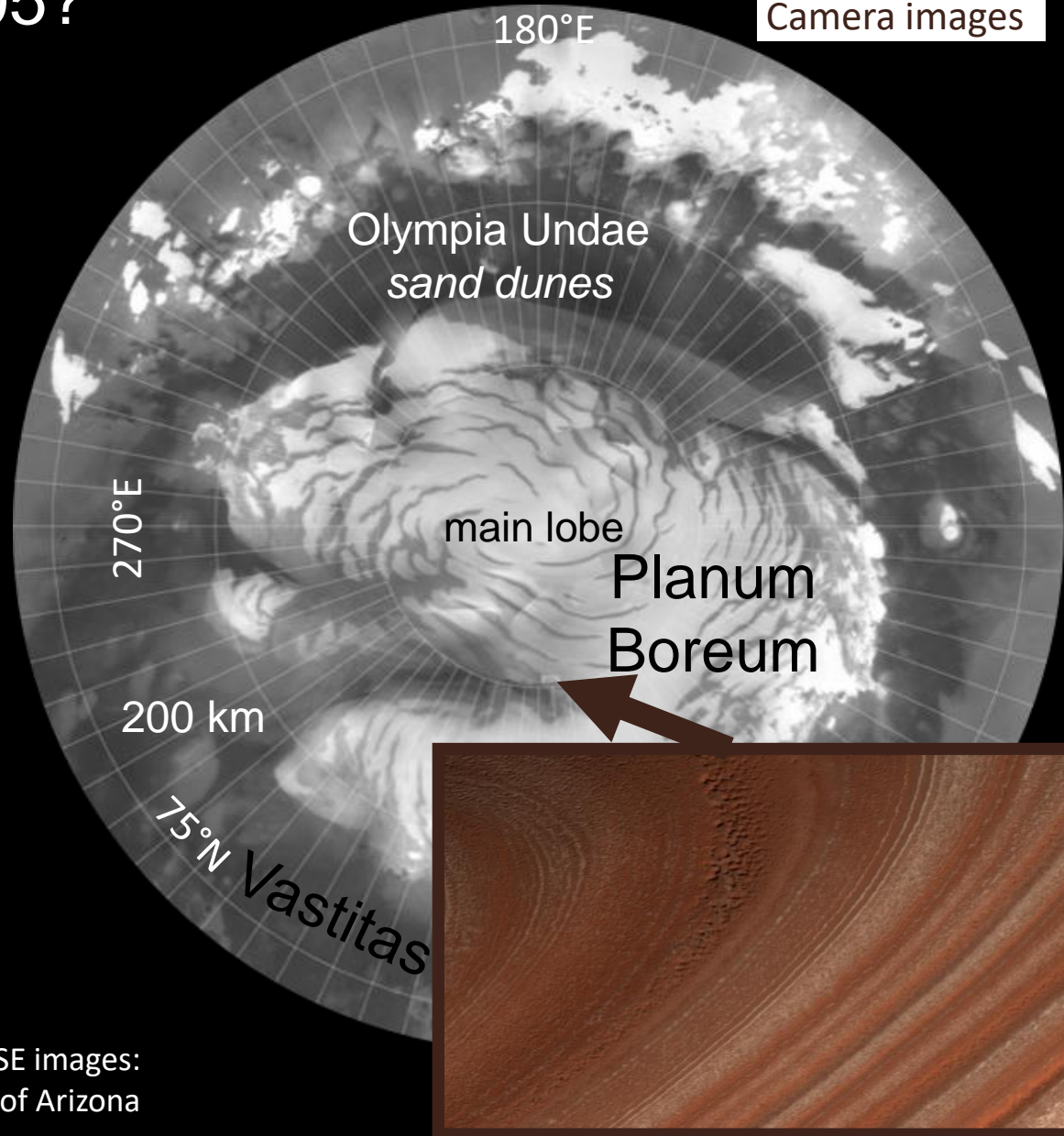
**Recent Mars: Ice and Climate Change**

**Present Mars**

# What did we know about *recent* Mars in 2005?

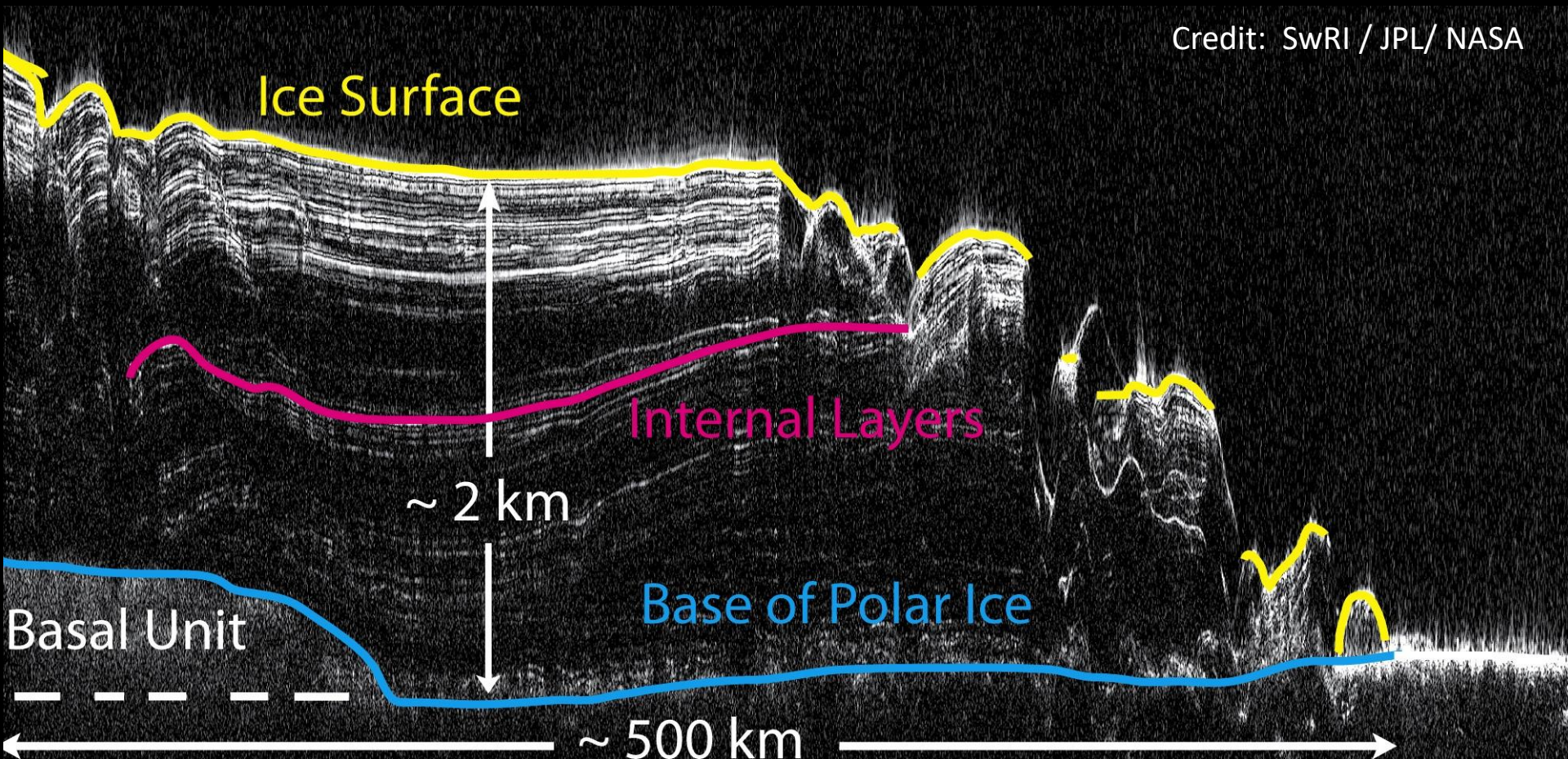
Mosaic of  
Mars Orbiter  
Camera images

- Ancient Mars
- Recent Mars
  - Polar cap layers, bottom?
  - Mid-latitude ice a possibility, but not certain
- Present Mars



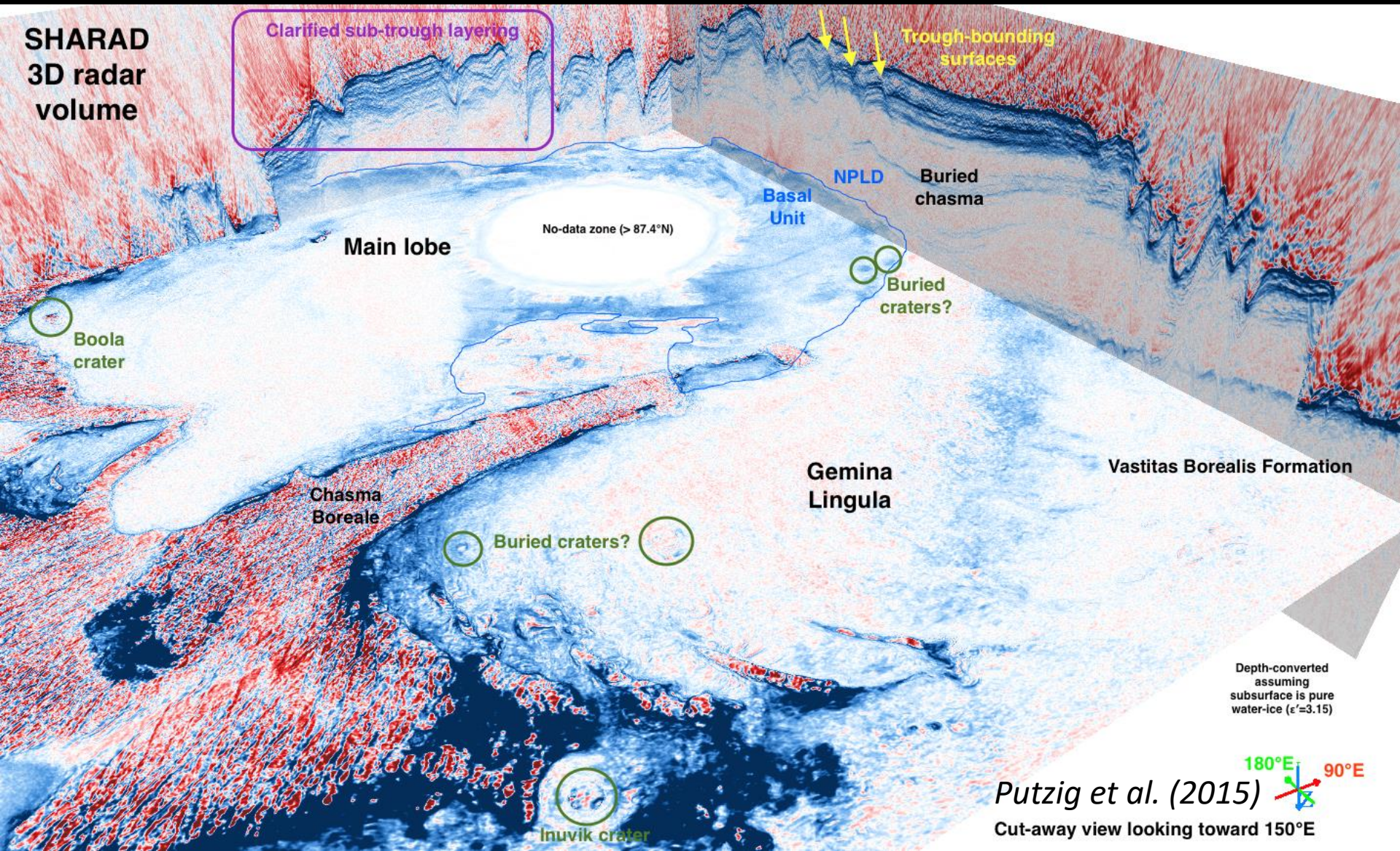
# SHARAD detections of Layers in the NPLD

Credit: SwRI / JPL / NASA



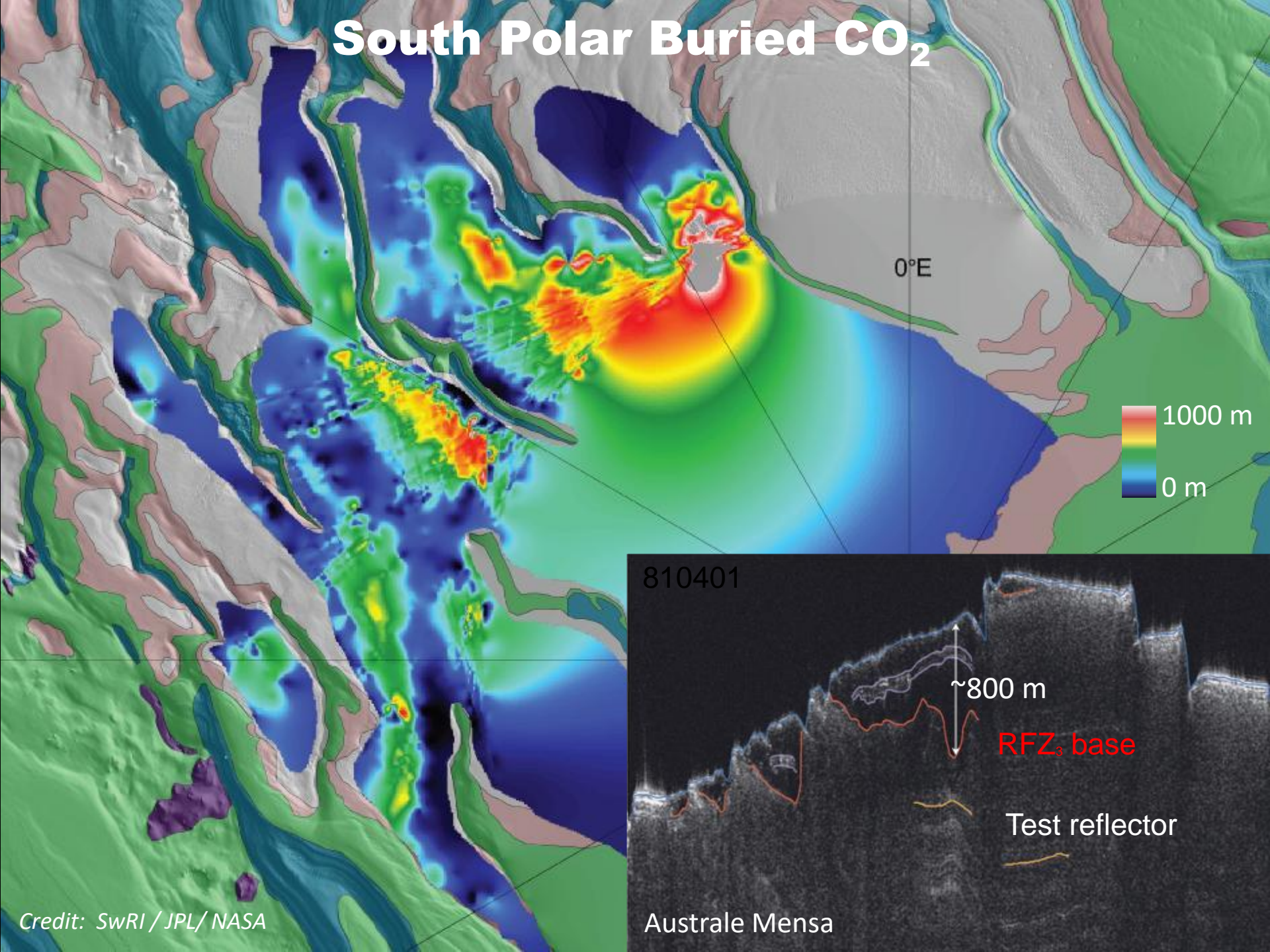


# Many SHARAD tracks enable a 3D view of the North Polar Cap

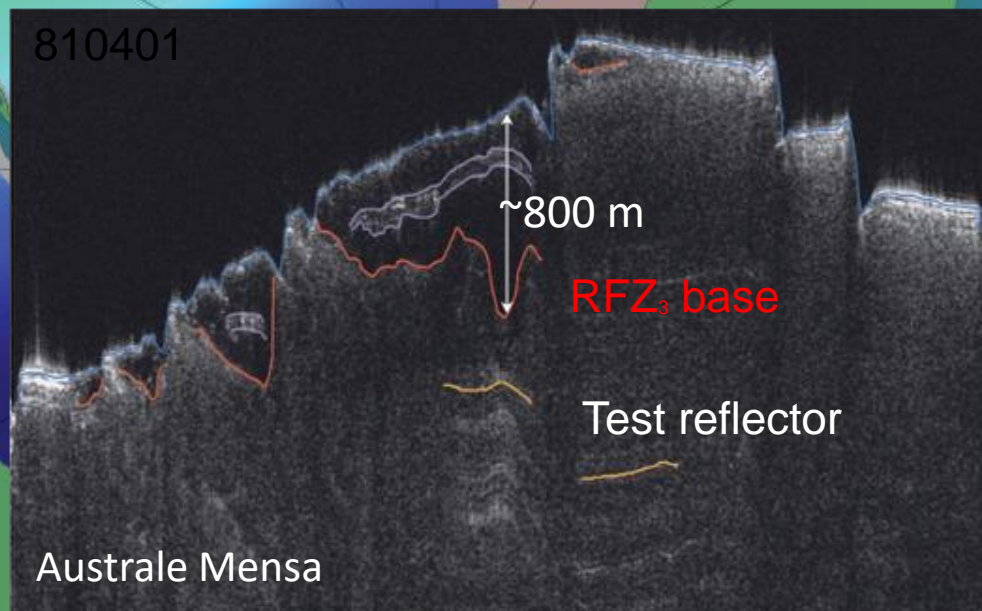




# South Polar Buried CO<sub>2</sub>



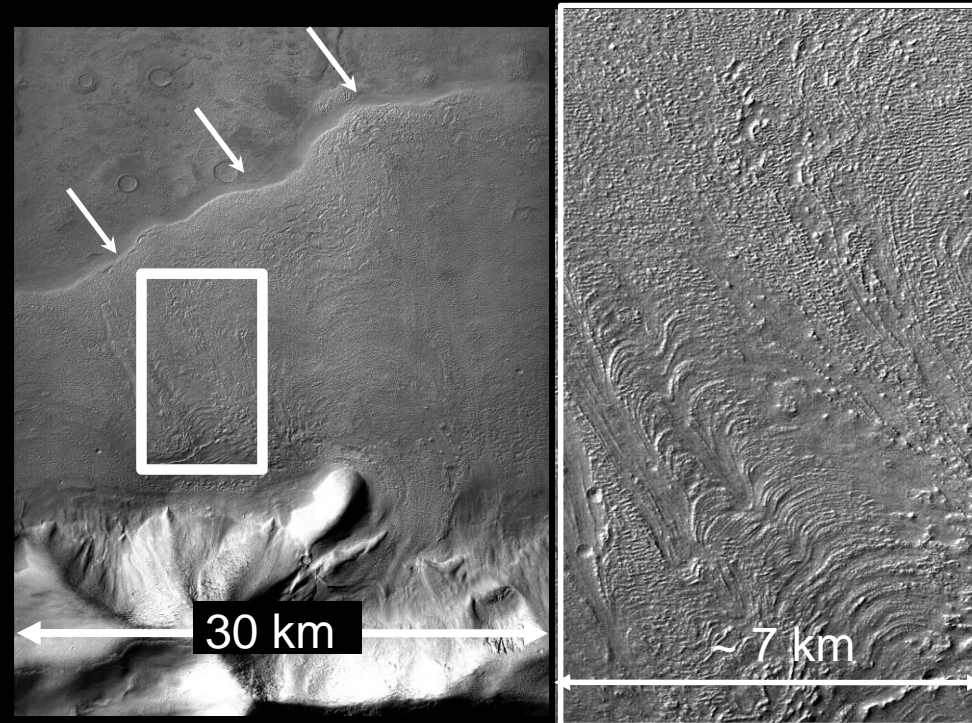
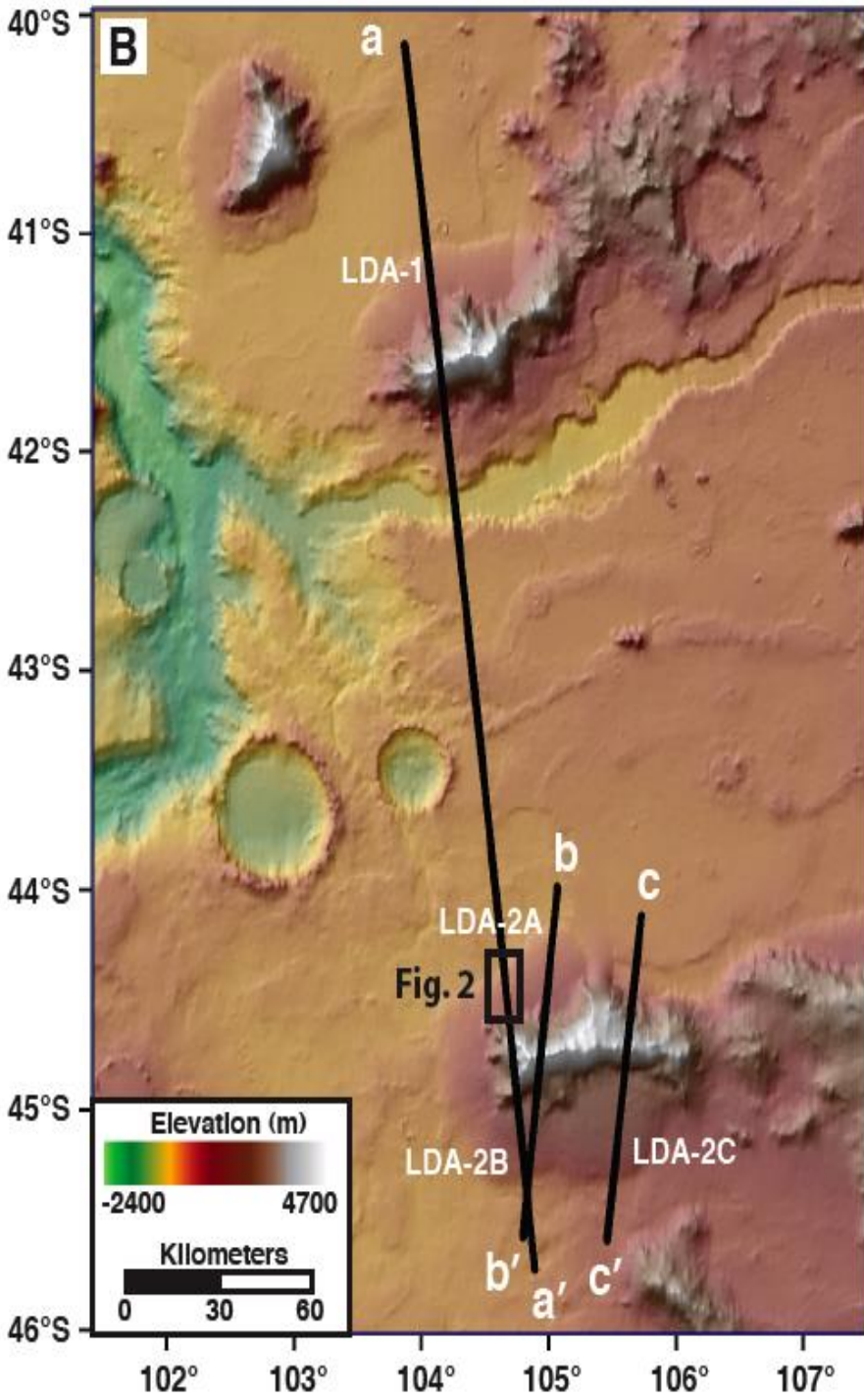
810401





# Lobate Debris Aprons

Confirmed by SHARAD to be  
debris-covered glaciers with  
> 95% ice



CTX image P03\_002294\_1349\_45S255W  
Credit: SwRI / MSSS / JPL / NASA



# MRO Science Results in Three Mars Eras

**Ancient Mars**

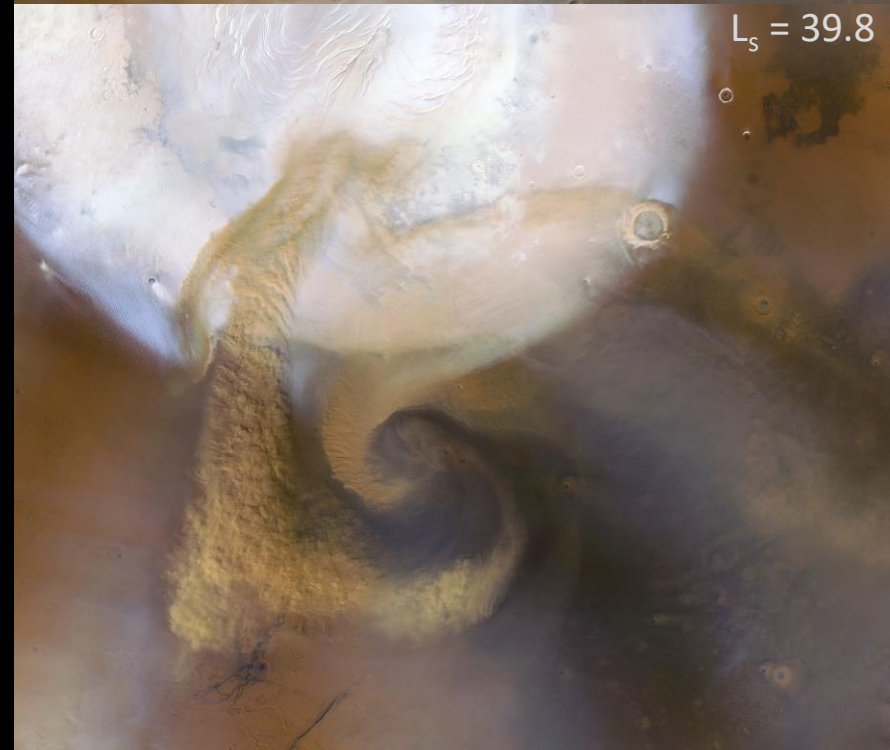
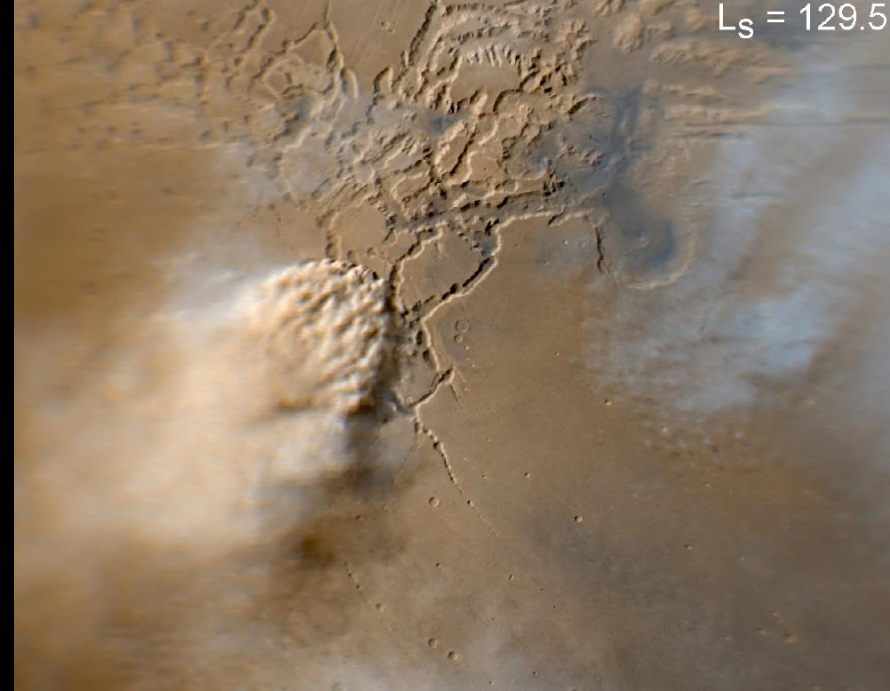
**Recent Mars**

**Present Mars: Unexpected Changes**

# What did we know about *present* Mars in 2005?

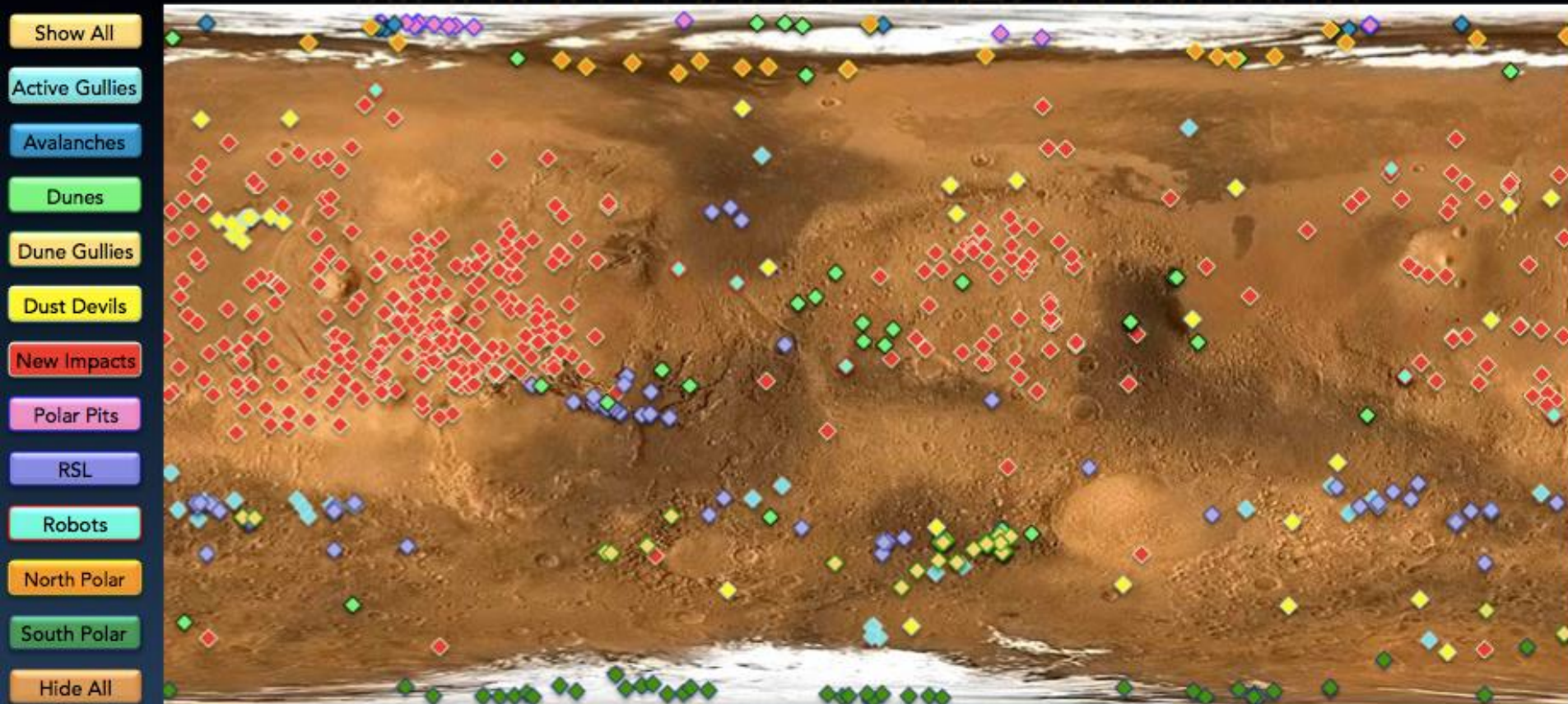
- Ancient Mars
- Recent Mars
- Present Mars
  - No liquid water on Mars today
  - Dunes, perhaps frozen from some ancient time
  - Formation of gullies
  - Vertical distribution of dust and water-ice unknown
  - Current impact cratering rate
  - Polar cap formation - CO<sub>2</sub> frost or snowfall

*Credit: MSSS / JPL / NASA*



# Mars is Dynamic!

## Martian Landscapes in Motion



(monitored by MRO/HiRISE)

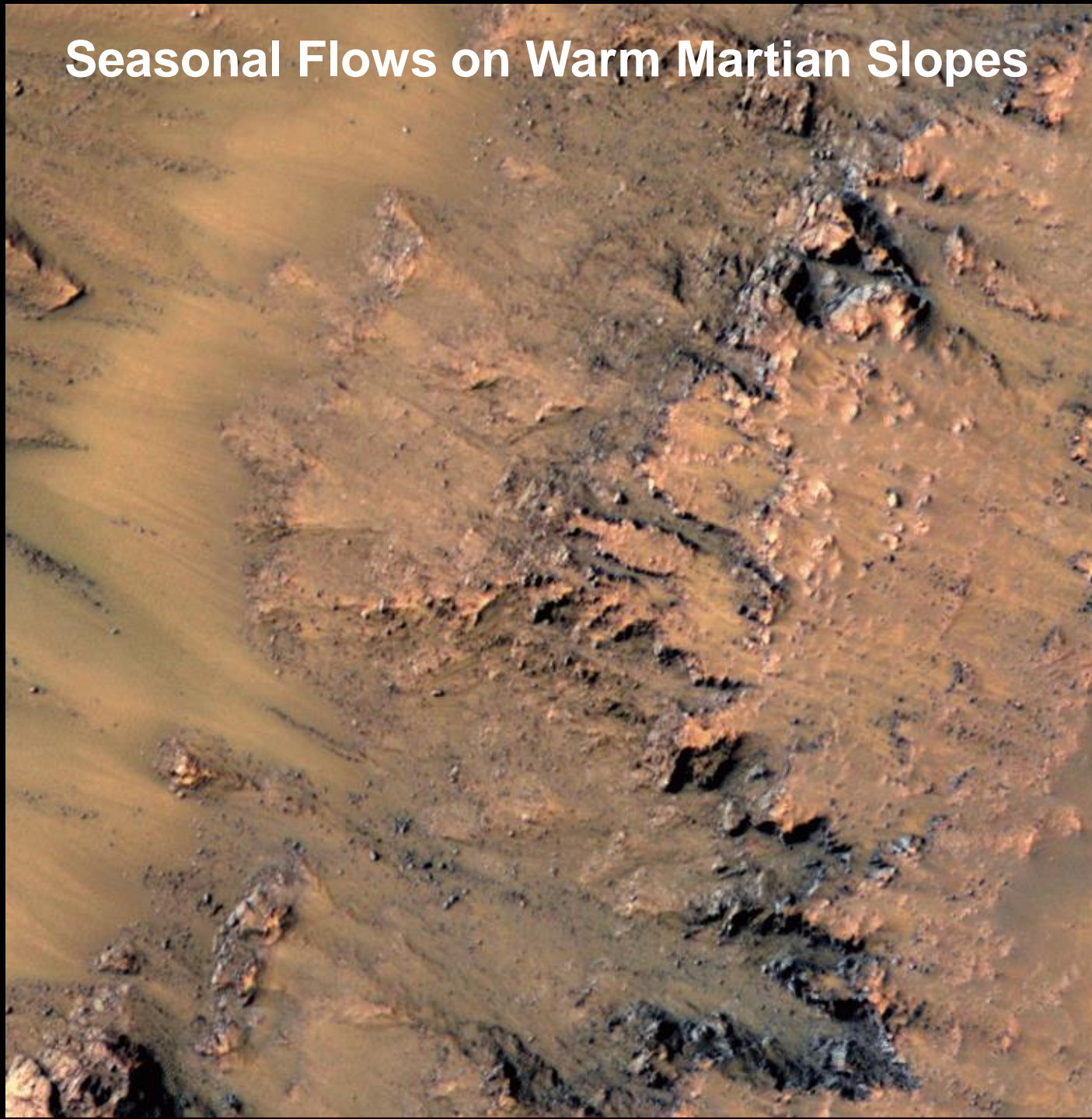
Credit: HiRISE / University of Arizona / JPL / NASA



# Seasonal Flows on Warm Martian Slopes

RSL =  
Recurring  
Slope Lineae

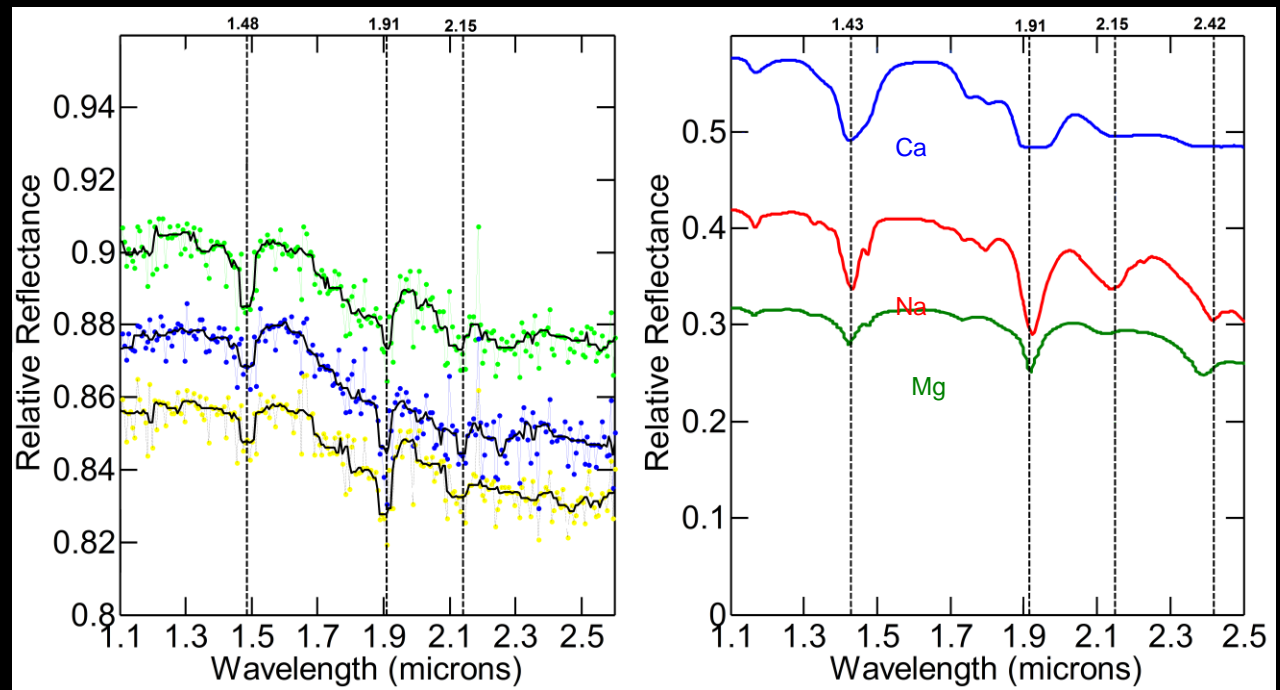
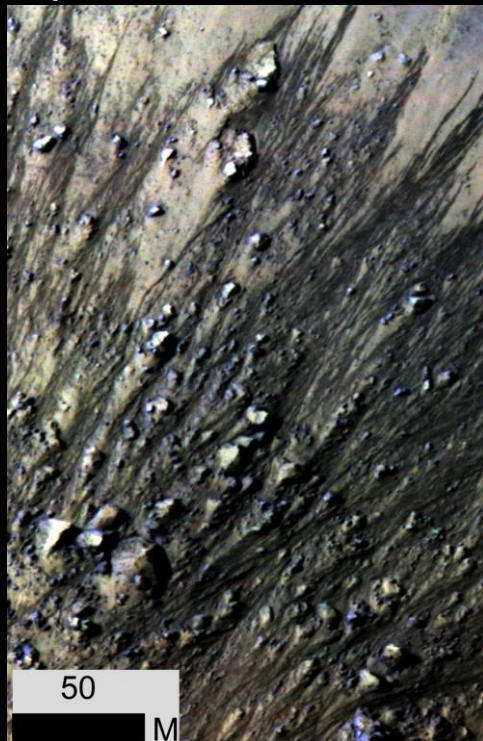
McEwen et al., Science (2011)  
Credit: HiRISE /  
University of Arizona / JPL / NASA



# RSL: Hydrated Perchlorate found by CRISM

- Discovery of hydrated perchlorates (salty water or perhaps watery salt)
  - Deliquescent -> easily takes up water from atmosphere
  - Decrease freezing point down to -70 C

McEwen et al., 2011, 2014  
Ojha et al. 2013, 2014, 2015



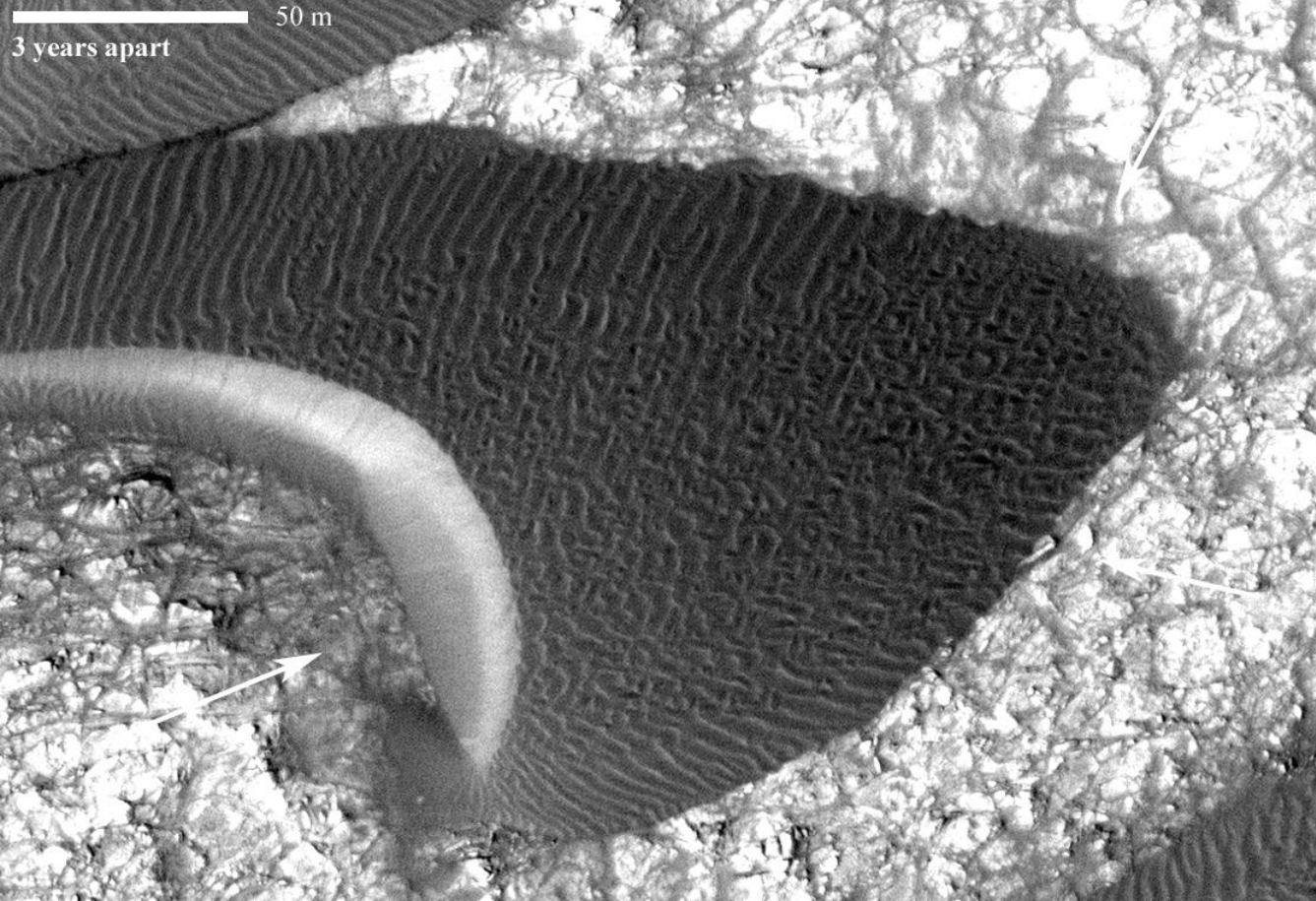
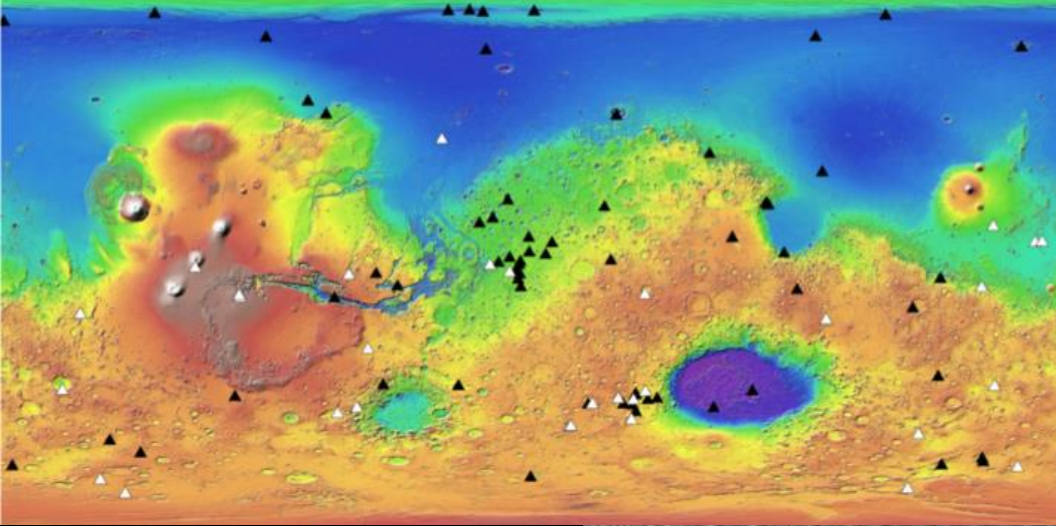
(left) RSL in Horowitz crater. (center) Single-pixel CRISM spectra.  
(right) Perchlorate salts measured in the lab.

Credit: CRISM / JHU-APL / JPL / NASA

Credit: HiRISE / University of Arizona / JPL / NASA



# Windy Mars



Dune motion  
observed globally

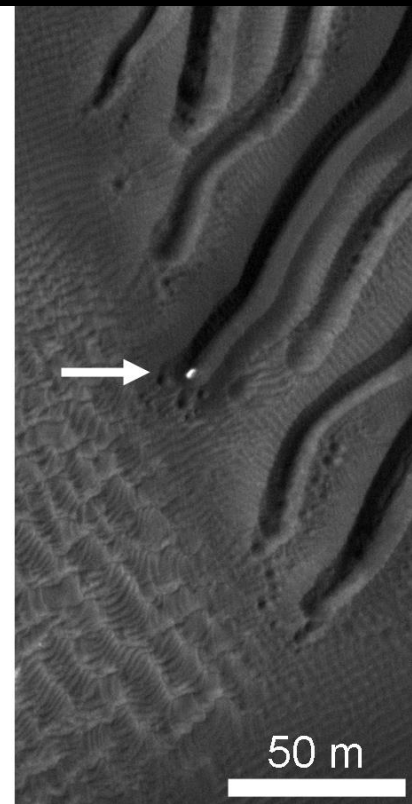
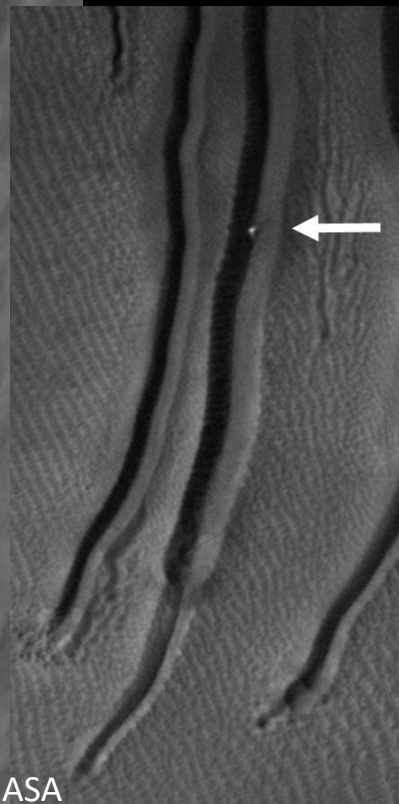
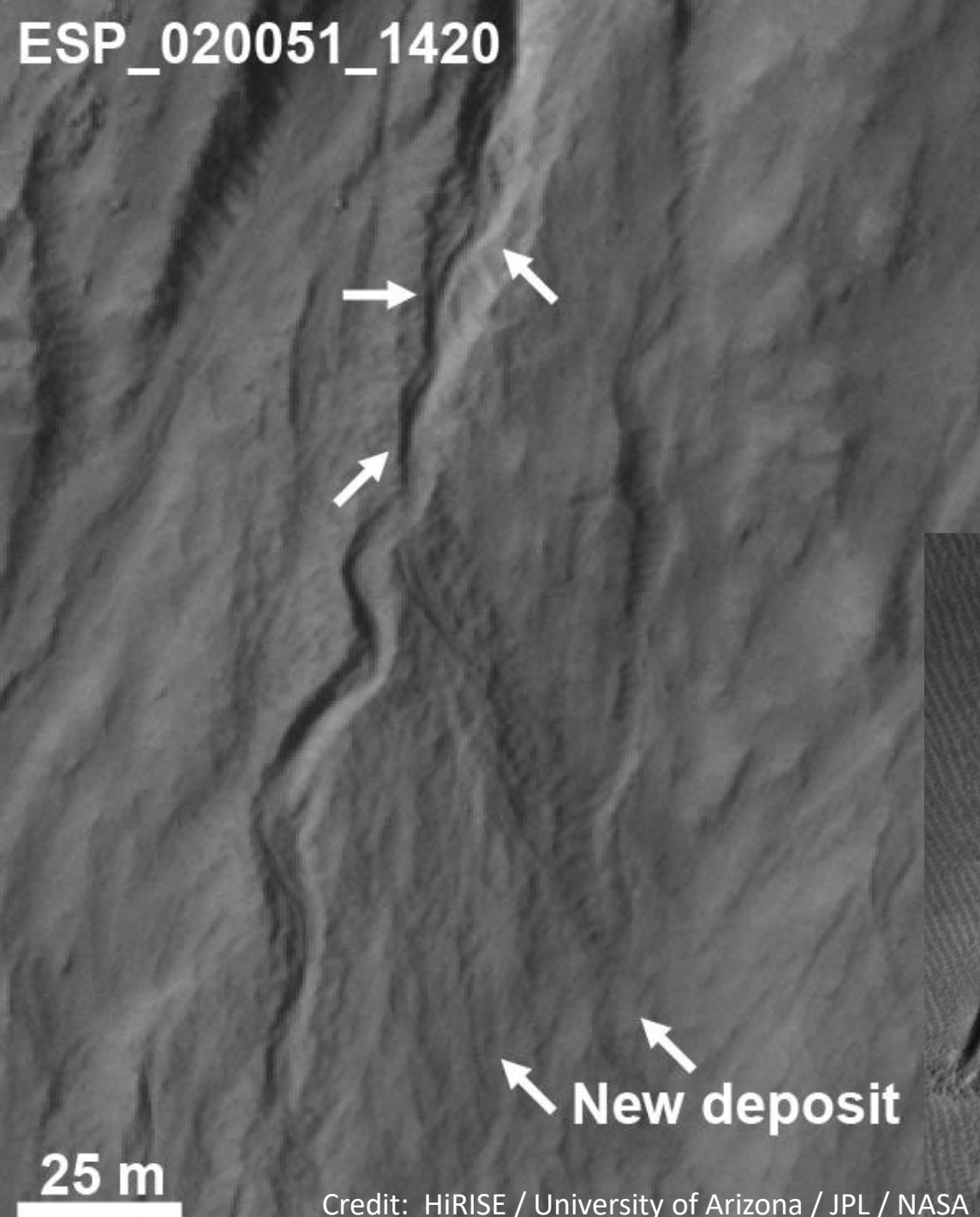
Black = active  
White = no activity  
observed (yet)

Credit: HiRISE / University of  
Arizona / JPL / NASA



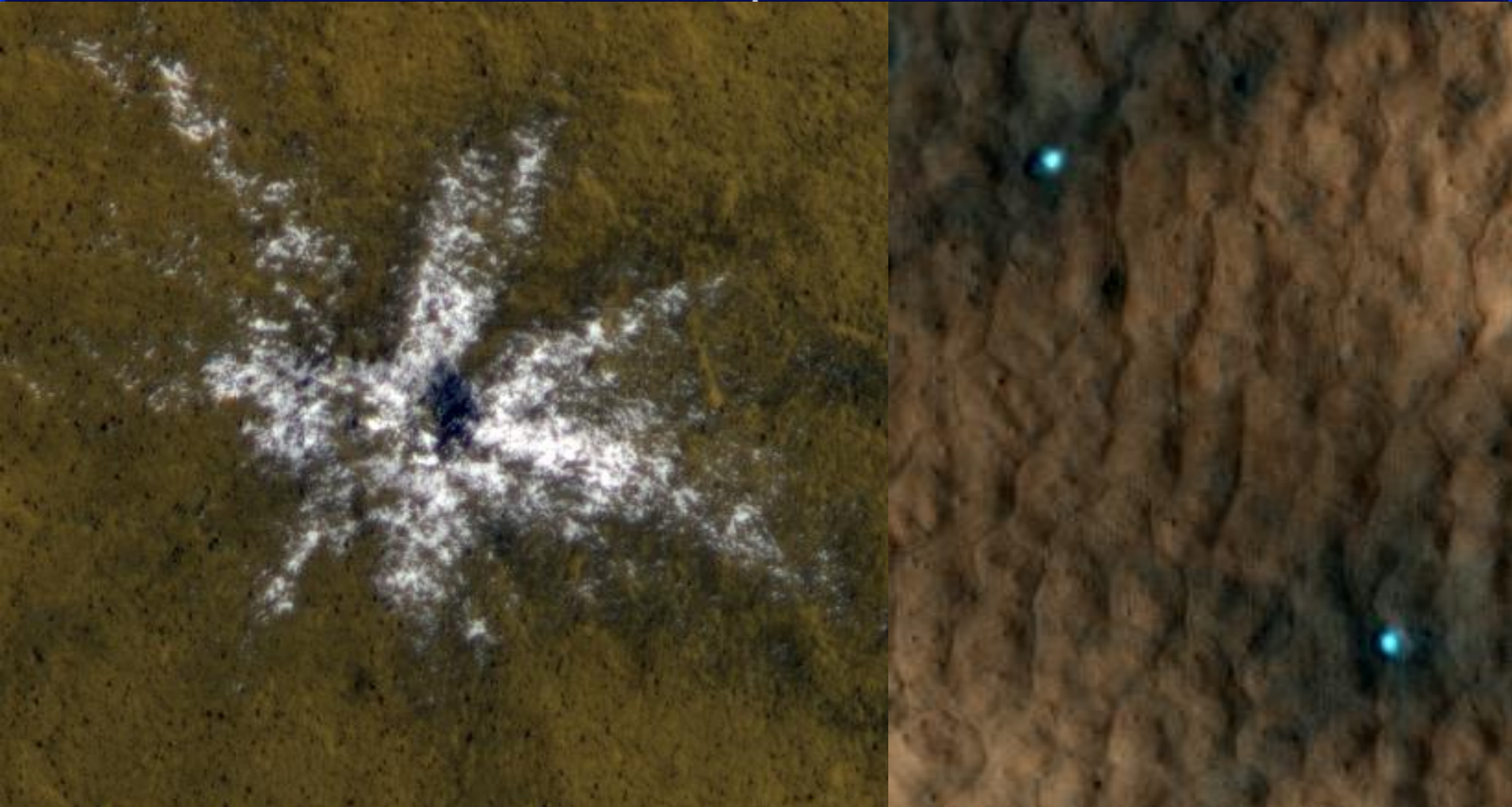
ESP\_020051\_1420

# Gullies



Credit: HiRISE / University of Arizona / JPL / NASA

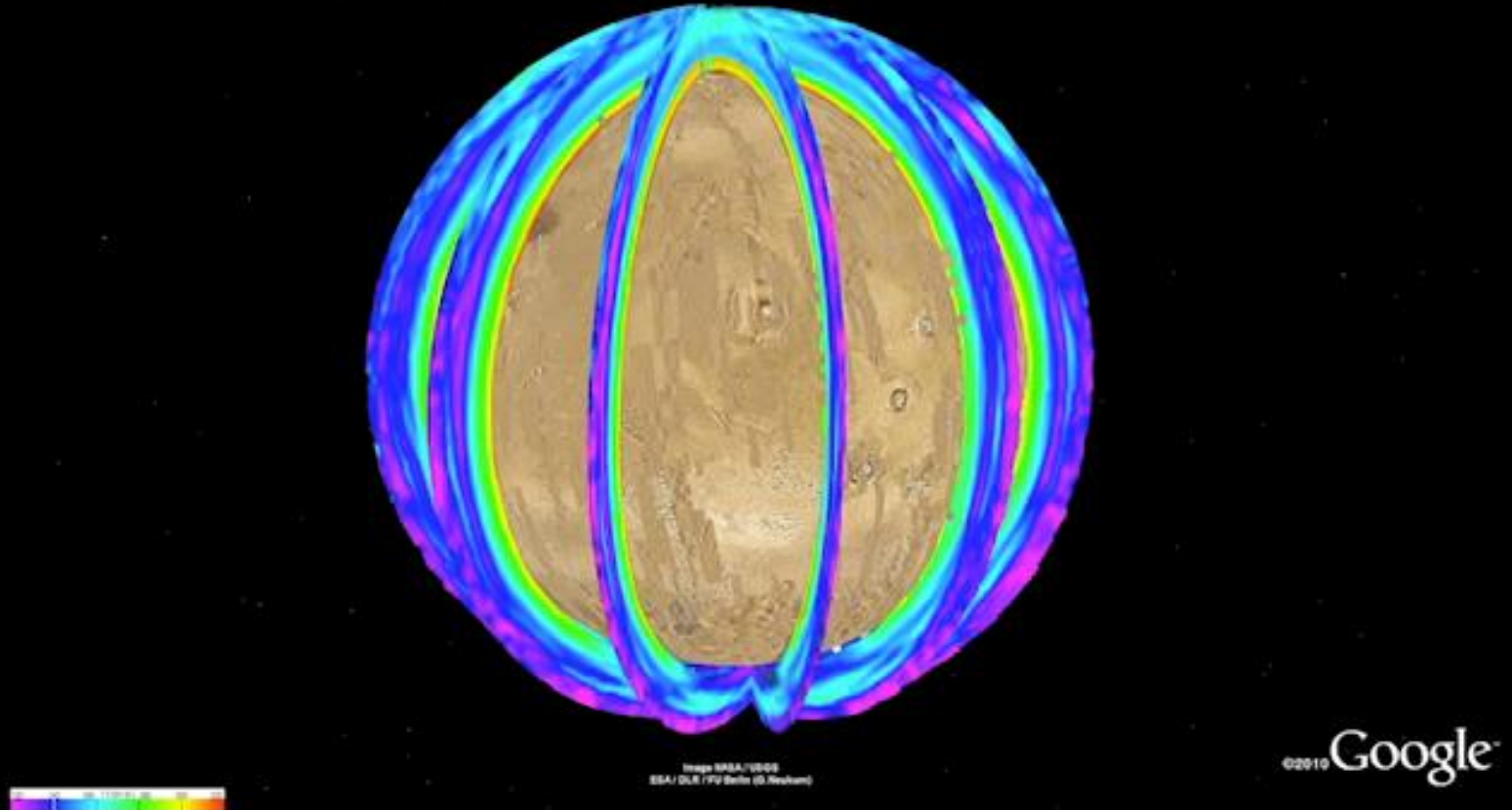
# New impact craters



HiRISE follows up on potential crater alerts

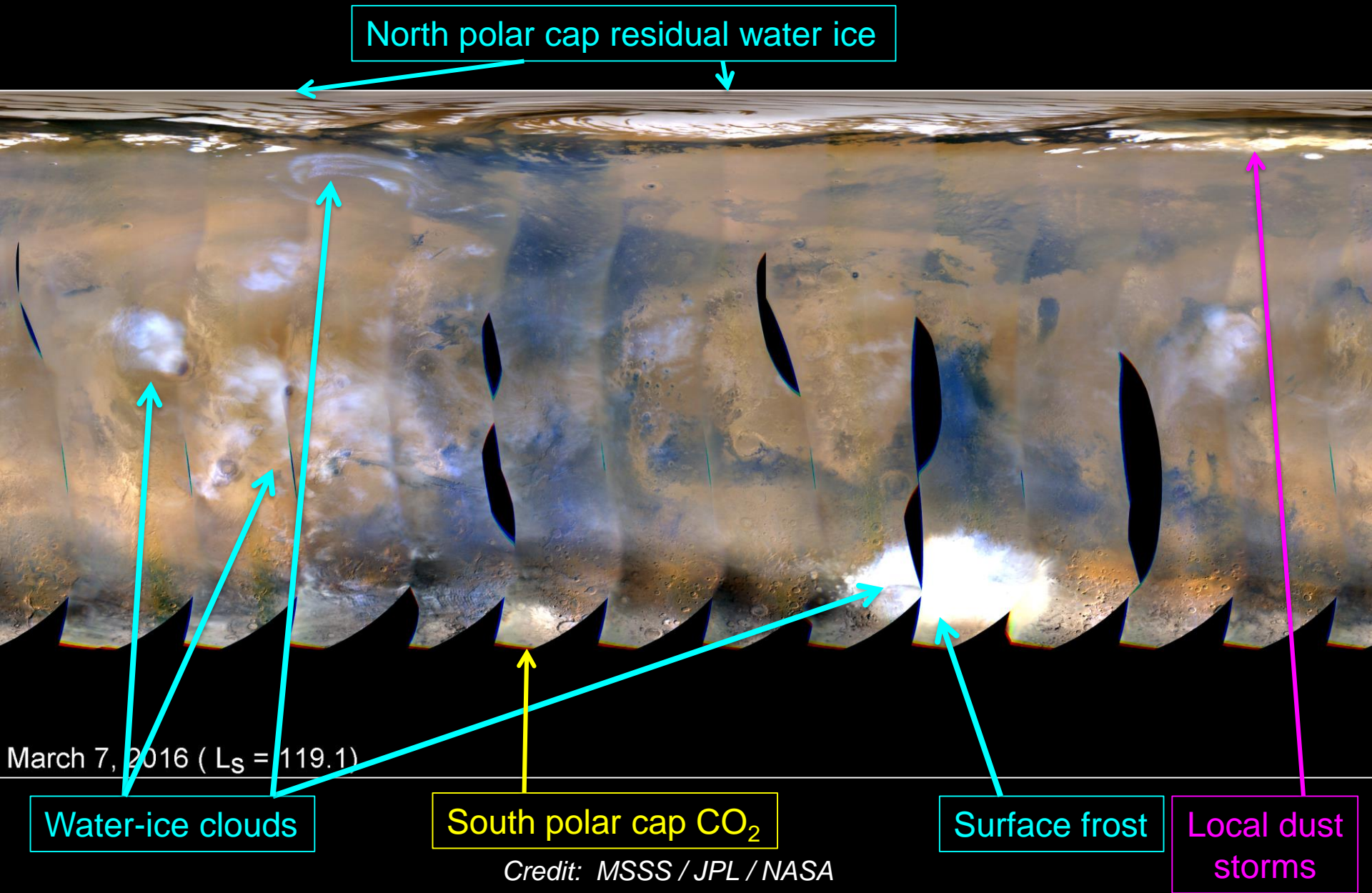
*Credit: University of Arizona / JPL / NASA*

# Atmospheric Profiles: Daily Global Sampling

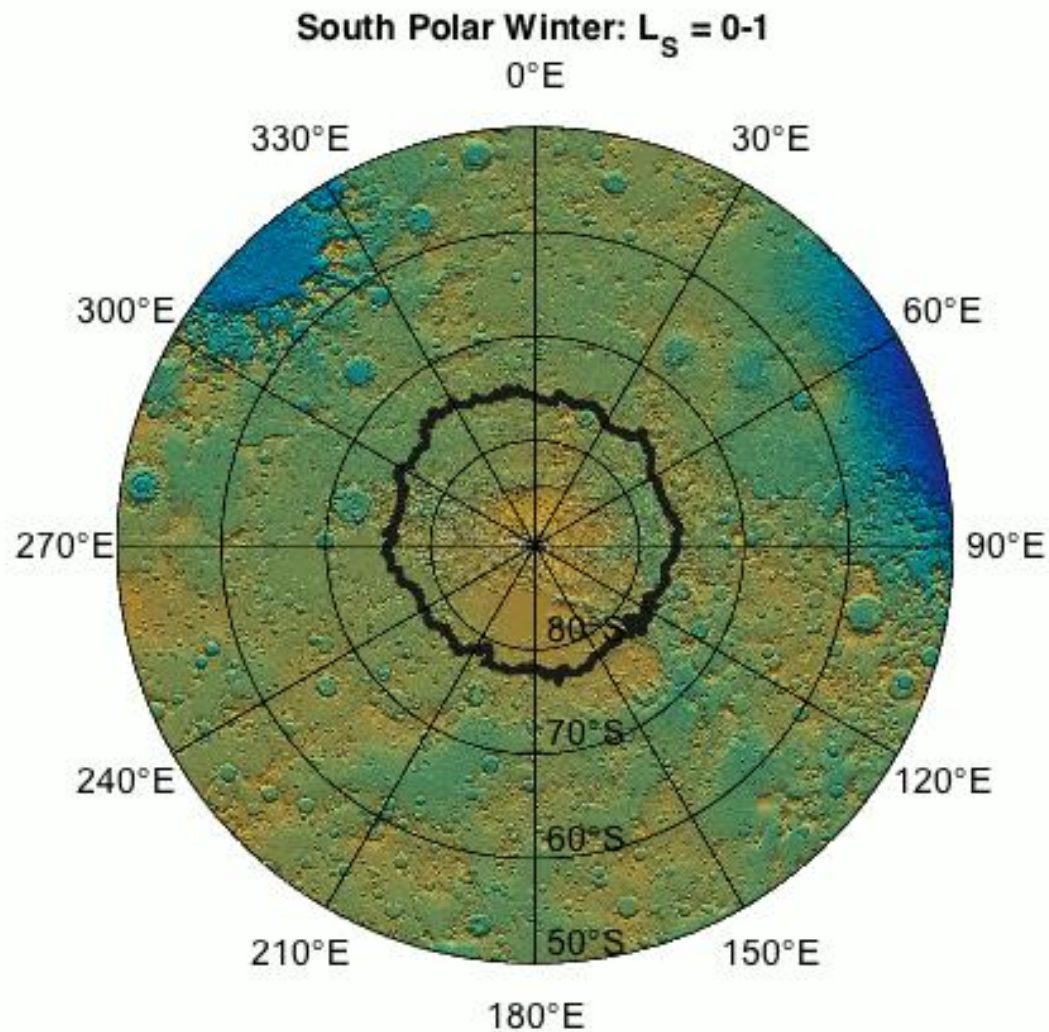




# Recent MARCI global weather map



# CO<sub>2</sub> Snow Clouds and Surface Snow: South Pole





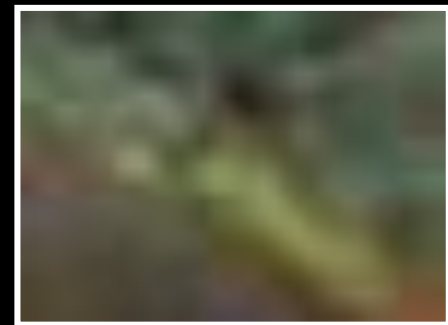
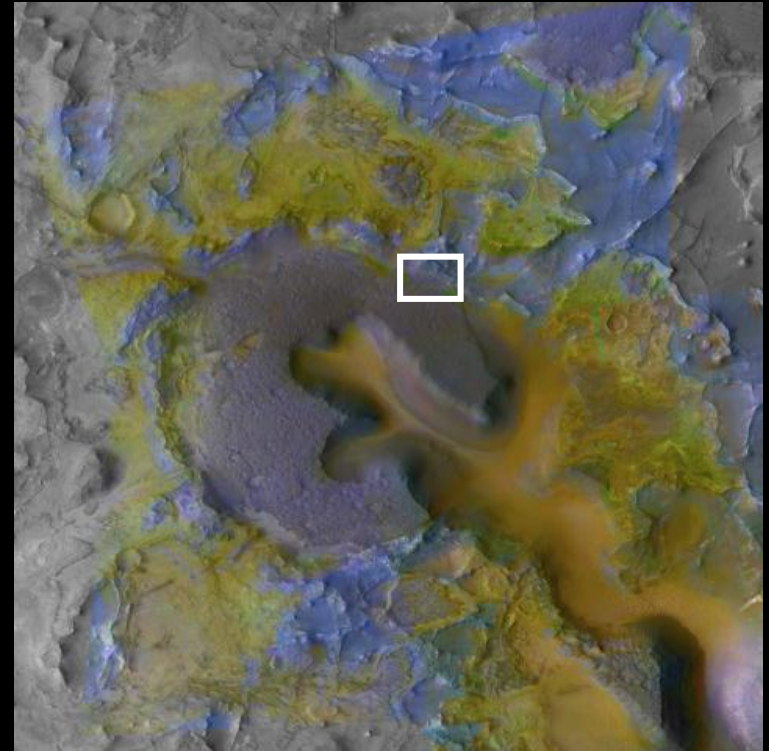
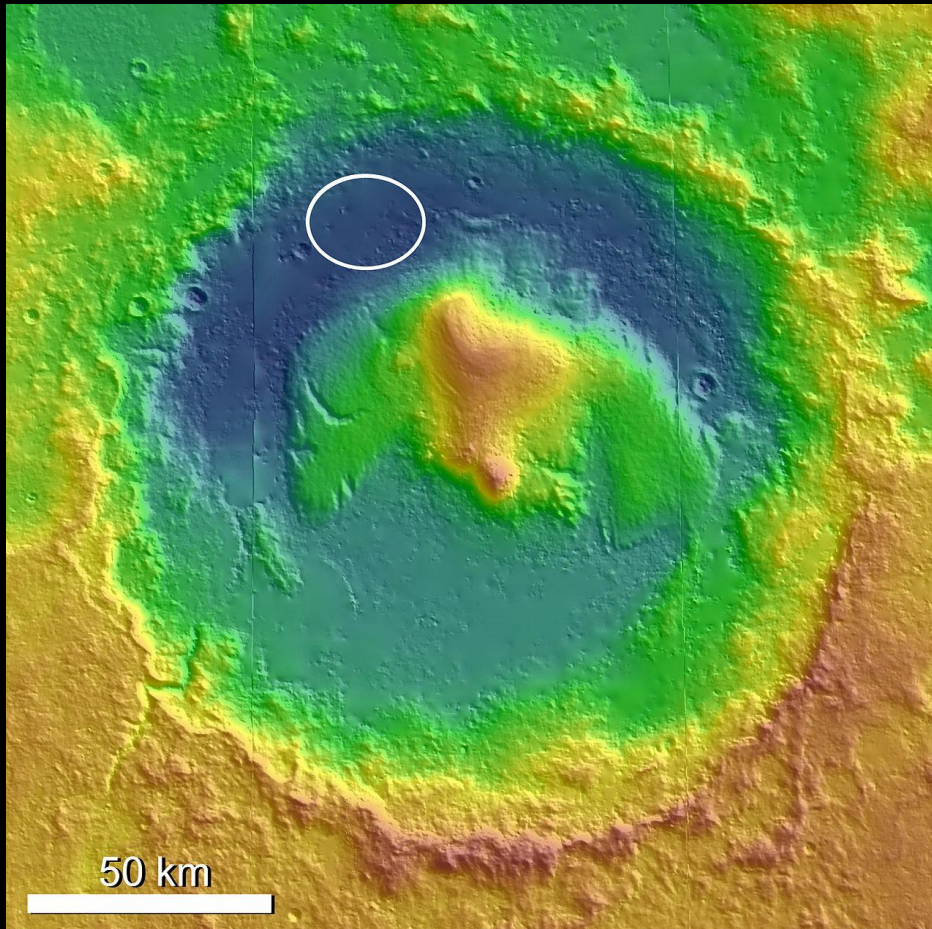
# Outline

- Why explore Mars?
- Mars Reconnaissance Orbiter overview
- Science results
- Support of other missions



# Support of other missions: Science

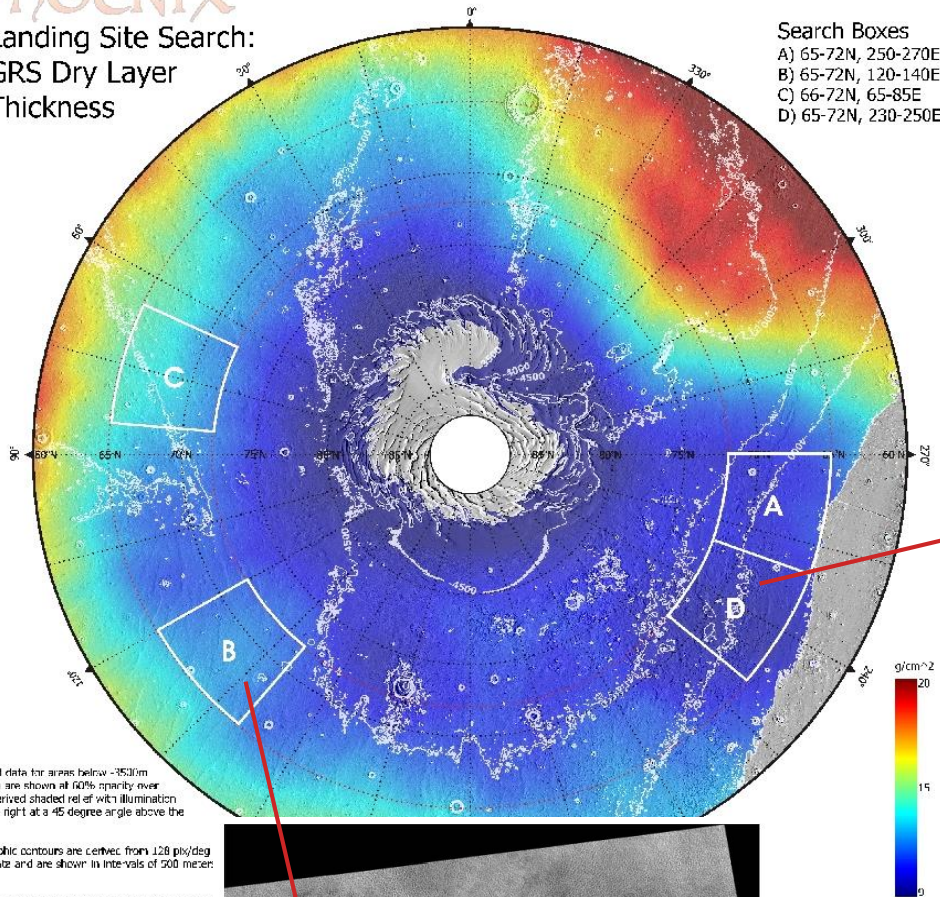
MRO *science*  
interpretation suggests  
landing locations





# Support of other missions: Landing site selection, characterization, certification

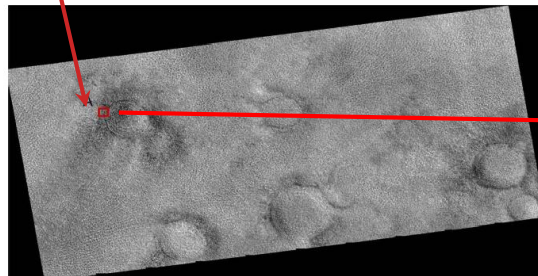
**PHOENIX**  
Landing Site Search:  
GRS Dry Layer  
Thickness



Calculated data for areas below -2500m elevation are shown at 60% opacity over MOLA-derived shaded relief with illumination from the right at a 45 degree angle above the horizon.

Topographic contours are derived from 128 phy/deg MOLA data and are shown in intervals of 500 meters.

Kim Deal, Washington University in St. Louis, cwest

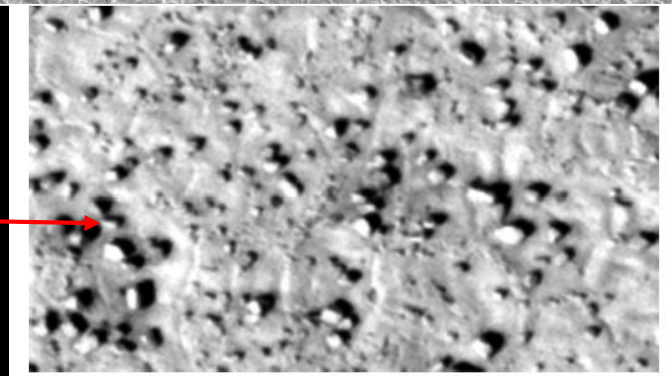


xstart: 5619  
Ystart: 6078

*HiRISE / UA / JPL / NASA*

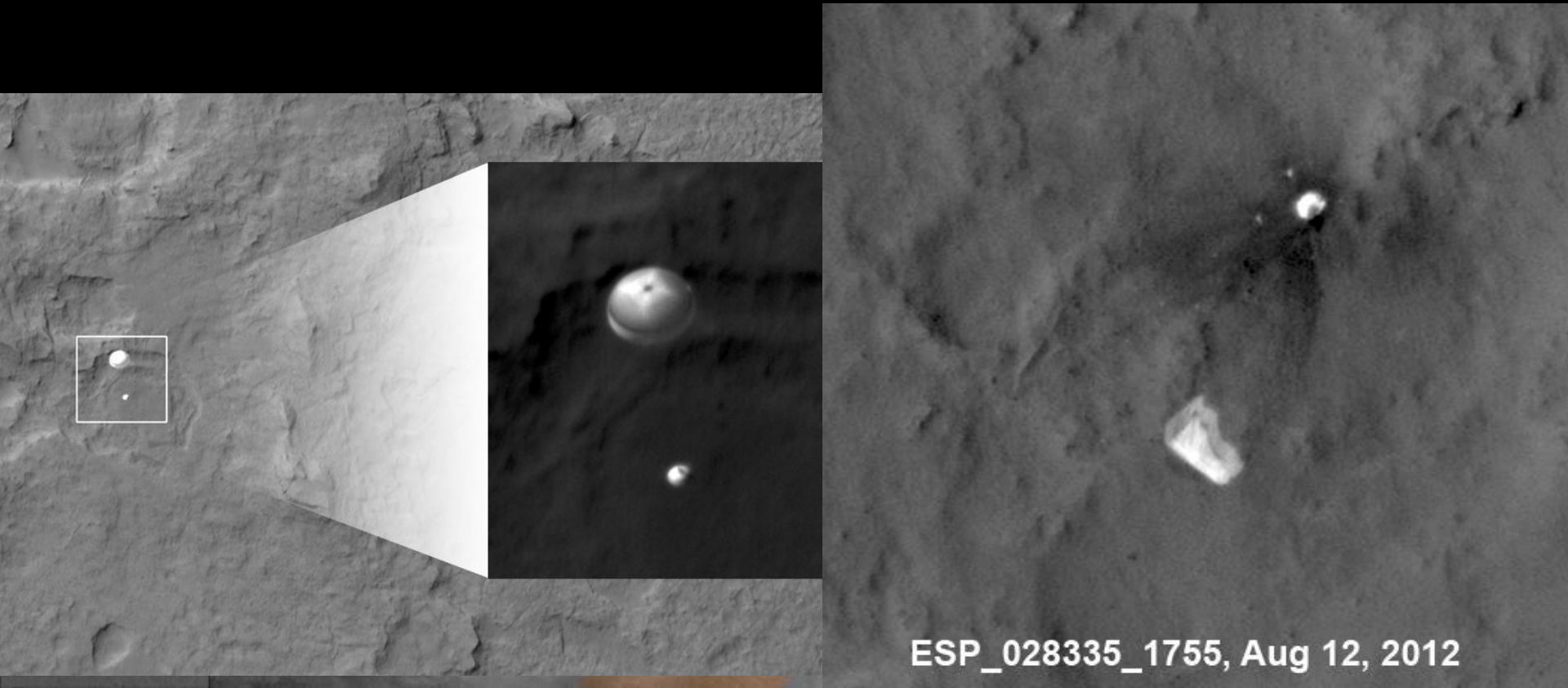
Rock  
Abundance  
CFA  
< 5%

100 m



# Support of other missions: Entry, Decent, and Landing

## MSL/Curiosity





# Support of other missions: Weather reports, rover path planning, data relay

MRO returns  
75% of Curiosity data  
450 Mb/day;  
>515 Gbits to date



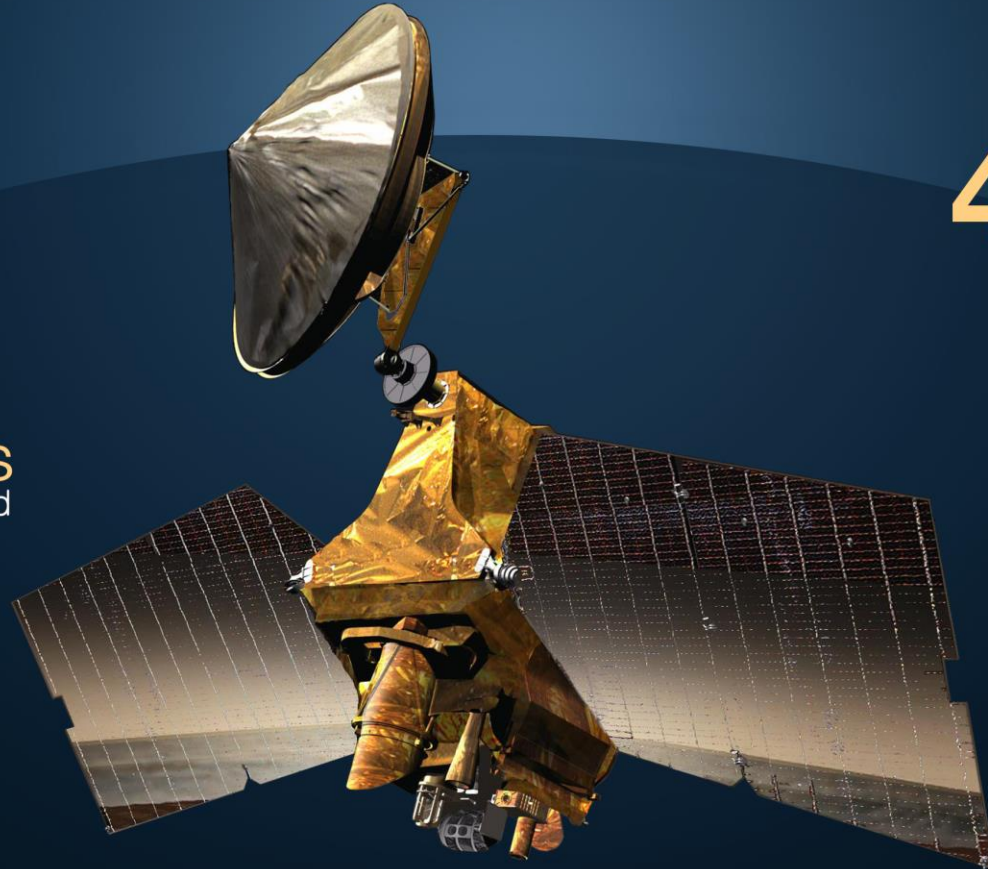
# Mars Reconnaissance Orbiter

## BY THE NUMBERS

**10** YEARS  
in orbit

**263** TERABITS  
of data returned

**956** MILLION  
MILES  
traveled since launch



**45,000** ORBITS

landing site  
scout  
for **7** MARS  
MISSIONS

**216,000+**  
images taken



# With thanks to

- Laurie Barge
- Bruce Cantor
- Dan Johnston
- David Kass
- Mike Malin
- Dan McCleese
- Alfred McEwen
- Sarah Milkovich
- Scott Murchie
- Than Putzig
- Rich Zurek
- And the entire MRO Team



**To find out more: <http://mars.jpl.nasa.gov/mro/>**